The Lake Enrichment Program: Methods for the Fertilization of Lakes in British Columbia 1970 to 1982

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THE LAKE ENRICHMENT PROGRAM: METHODS FOR THE FERTILIZATION OF LAKES IN BRITISH COLUMBIA 1970 TO 1982

by

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ABSTRACT

Stephens, K. and J. G. Stockner. 1983. The lake enrichment program: methods for the fertilization of lakes in British Columbia 1970 to 1982. Can. Tech. Rep. Fish. Aquat. Sci. 1192: iii + 51 p.

This report describes the materials and methods used in the fertilization of lakes in British Columbia with inorganic phosphorus and nitrogen from 1970 to 1982. The primary purpose of these lake treatments was to enhance the growth and survival of rearing juvenile sockeye salmon (Oncorhynchus nerka).

Key words: lake fertilization, sockeye salmon, limnology.

RÉSUMÉ

Stephens, K. and J. G. Stockner. 1983. The lake enrichment program: methods for the fertilization of lakes in British Columbia 1970 to 1982. Can. Tech. Rep. Fish. Aquat. Sci. 1192: iii + 51 p.

Les auteurs décrivent les matériaux et les méthodes utilisés pour la fertilisation lacustre avec du phosphore inorganique et de l'azote en Colombie-Britannique de 1970 à 1982. Le but principal des traitements de ces lacs était la stimulation de la croissance et de la survie des saumons sockeyes juvéniles d'élevage (Oncorhynchus nerka).

Mots-clés: fertilisation lacustre, saumon sockeye, limnologie.

Fig. 1. Location of British Columbia lakes treated by the Lake Enrichment Program.

INTRODUCTION

Large scale experimental enrichment of sockeye salmon (Oncorhynchus nerka) nursery lakes with nitrogen and phosphorus fertilizers has been carried out in British Columbia since 1970. Controlled additions of solutions of fertilizers have been applied to the epilimnian of selected lakes at weekly intervals during the growing season (April to October). The enrichment program began in 1969 as a scientific experiment carried out by the Fisheries Research Branch to test the effectiveness of the addition of chemical fertilizers in stimulating and sustaining primary and secondary production in lakes so as to enhance the in-lake growth and survival of juvenile sockeye salmon (Parsons et al. 1972, Stockner 1977). Based on encouraging returns of adult fish to Great Central Lake, fertilization of Henderson Lake was undertaken in 1976 and the program was expanded with funding provided by the Salmonid Enhancement Program (SEP). Since 1977, more lakes have been added and the current program includes 13 sockeye salmon nursery lakes (Stockner et al. 1980).

This report describes the methods and materials used to chemically enrich sockeye salmon nursery lakes in British Columbia from 1970 to 1982.

MATERIALS

FERTILIZERS

Lakes were treated with aqueous solutions of nitrogen and phosphorus fertilizers. Agricultural fertilizers were used because they were the least expensive source of inorganic nitrogen and phosphorus available. The fertilizers used are listed in Table 1, and were about 96% water soluble. The insoluble remainder was a gypsum binder. The fertilizer 27-14-0 had a nitrogen to phosphorus atomic weight ratio (N:P) of 10:1. Separate solutions of ammonium phosphate and ammonium nitrate were prepared after 1971 to allow for adjustment of the N:P ratio.

WATER

Water used to prepare fertilizer solutions at Great Central Lake during the 1970 to 1973 experiments was taken from the epilimnion of the lake. Water for mixing was taken from deep wells during 1976 and 1977. This eliminated the risk of dissemination of pathogenic agents (G. R. Bell, personal communication). Bacteriological examination of the water supplies used for solution preparation at Smithers and Campbell River for the expanded program met the criteria for potable water (Snook 1980).

FERTILIZER COSTS

The cost (1978) for 50 kg of the ferilizer 11-55-0 was 46 cents/kg P, and the cost of an equivalent amount of technical grade monoammonium phosphate was 58 cents/kg P. The cost (1980) of shipping fertilizer from the supplier in Abbotsford, B.C. to the mixing facility at Smithers, B.C. was 4.5 cents/kg P for the dry fertilizer. The cost of shipping an equivalent amount of commercially available aqueous solutions of N and P would have been 26 cents/kg P plus the cost of returning empty containers.

FERTILIZER SOLUTION PREPARATION

Great Central Lake 1970 to 1973

A platform was constructed at lake side to support a 2730 liter (600 gallon) and a 9092 liter (2000 gallon) fibreglass tank. 907 kg (1 ton) of fertilizer was added to 1273 liters (280 gallons) of water, pumped from the surface of the lake into the smaller tank. The mixture was recirculated through 3.8 cm (1.5 inch) pumps designed to handle liquids with entrained solids, the action of the pumps tended to break up the fertilizer granules and hasten solution. Small additions of fertilizer, followed by vigorous stirring, was the most efficient method of solution. After the fertilizer was completely dissolved the solution was pumped into the larger holding tank. This procedure was repeated until all the fertilizer required for one week's treatment was dissolved. The insoluble binder that settled out on standing was resuspended by stirring prior to loading the distribution vessel. Plastic tanks and plumbing were used and pumps and motors were replaced annually, because of the corrosive nature of the fertilizer solutions. The final concentration of the treatment solution was 4.54 tonnes (5 tons) 27-14-0 in 10.88 tonnes (12 tons) of solution or 0.11 kg N. kg^{-1} solution and 0.025 kg P. kg^{-1} solution at a 10 N to 1 P atom weight ratio. Separate solutions of phosphate (11-55-0) and nitrate fertilizer (34-0-0) were prepared after 1971 to allow for adjustment of the nitrogen to phosphorus ratio.

Expanded program of multi-lake experiments since 1977

A three tank system was used to prepare fertilizer solutions since 1977. Methods of solution and mixing were similar to those previously described. Water was measured to the tanks by meter to the nearest 4.5 liters (1 gallon). Each tank was fitted with a sight gauge graduated at 45 liter (10 gallon) intervals. Phosphate and nitrate solutions were prepared separately in 45,400 liter (10,000 gallon) tanks. Ammonium nitrate absorbs heat on dissolving and the tanks' contents tended to freeze, and the minimum solution times at temperatures below 15°C were about 2 days. Complete solution was indicated by the absence of granules in the tanks. The final mixture, with the required N:P ratio as given in the Treatment Schedule, was prepared from measured quantities of the two component solutions, which were

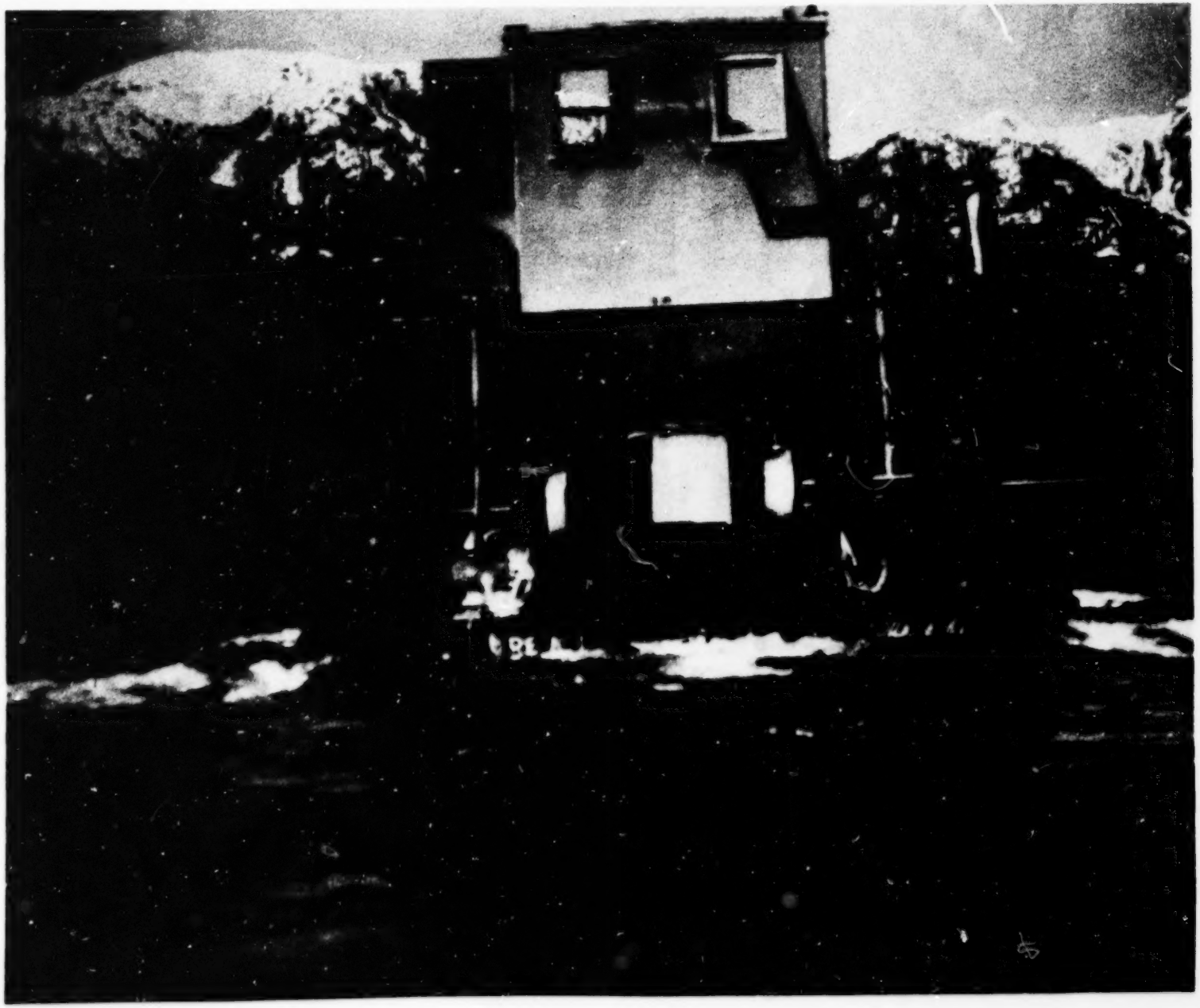

Fig. 2. Application by barge to Great Central Lake, 1971.

pumped to a 22,700 liter (5000 gallon) holding tank for final mixing before loading the distribution aircraft. Measurement of solutions from the tanks was made by using the installed sight gauge.

FERTILIZER STORAGE

Fertilizers were stored in a locked shed during the initial experiments at Great Central Lake to prevent vandalism and theft. The wooden shed floor was covered with two layers of plastic film and spilt fertilizer was promptly cleaned up as a precaution against fire. At Campbell River airport and at other flying bases subsequently used for the expanded program, the fertilizer was stored in the open in a guarded enclosure. The 25 kg bags were stacked 1 tonne to a pallet and covered with plastic tarpaulins to prevent damage from wind, rain and sunlight. The nitrate and phosphate fertilizers were piled separately to avoid confusion in solution preparation. No oil or gasoline was kept in the vicinity of the fertilizers as a precaution against fire. Spilt fertilizer was cleaned up immediately and rebagged in plastic sacks.

FERTILIZER APPLICATION

Boat

From 1970 to 1973, fertilizer was applied to Great Central Lake from boats and barges (Fig. 2). An 11 m aluminum launch was fitted with a tank capable of holding 1.8 tonnes (2 tons) of fertilizer solution. Six return trips between the mixing site and the fertilized area of the lake were required to deliver a full week's treatment of fertilizer. In a later season a self-propelled barge, capable of carrying the total weekly amount of fertilizer solution, was used to distribute the fertilizer treatment (Fig. 2).

Fertilizer was also distributed from a boat at Mohun Lake. This small 990 ha lake was fertilized from 1977 to 1979 by the Fish and Wildlife Branch, Department of the Environment, Province of British Columbia. A 6.3 m, 50 h.p. outboard powered launch was fitted in the bow with a removable 182 liter (40 gallon) fibreglass tank. The boat was able to plane at 12 knots when carrying a 136 liter (30 gallon) load of fertilizer and two persons.

Fertilizer was distributed to the lake from boats by injecting the solution into the propeller stream with a pipe from the holding tank fitted to discharge in the vicinity of the propeller hub. Fertilizer was allowed to flow out under gravity at a controlled rate determined by the volume of solution to be dispensed within a given area. To discharge the solution at depths of 10 m for special experiments, a hose was fastened to a depressor on a wire cable and the outboard end of the hose was towed at the required depth. Fertilizer solution was pumped from the holding tank through the discharge hose using a 1/2 h.p. centrifugal pump. The flow rate was regulated by a shut-off valve on the discharge side of the pump.

Fig. 3. Aerial application by Douglas DC6B to Lowe Lake, 1980.

Aircraft

Fertilizers were applied to lakes by air since 1976 (Fig. 3). The method overcame the difficulties and costs associated with overland access to most of the treated lakes, and the construction of access roads, docks and mixing sites at each lake.

The carrier aircraft used in this program was based at an airport located the least flying distance from all treated lakes. The airport also provided easy road access for fertilizer deliveries. Preparation of fertilizer solutions and quality control of mixing and application procedures were also simplified by the single location. Campbell River, Abbotsford and Smithers airports have been used as bases since 1976, Campbell River airport was the only flying base used by the program in 1982.

The aircraft used to apply fertilizer during these experiments has been a Douglas DC 6B.,chartered from Conair Aviation Ltd., Abbotsford, B.C. The aircraft was fitted with internal tanks constructed from epoxy coated aluminum and had a carrying capacity of about 12 tonnes of fertilizer solution, allowing for the treatment of all but the largest lakes in one flight, or the sequential treatment of several smaller lakes in a flight.

The aircraft's holding tanks were loaded with the appropriate amount and mixture of fertilizer solution, depending upon the number and size of the lakes to be fertilized on a given flight. The method of discharging the fertilizer solution from the aircraft was to pump the tanks contents to three ports mounted on the rear stabilizer, one in the center of the after edge, and one on each extreme outer edge (see Fig. 3). The rate of discharge was regulated from the aircraft's flight deck, and was determined from the amount of fertilizer to be discharged, the area of the lake to be fertilized and the speed of the aircraft over the ground. On approaching a lake to be treated the aircraft reduced speed and descended to a level where the discharged material would fall to the lake surface and not drift on to shore, about 15-30 m altitude. The discharge formed a cloud of light rain, approximately 30 m wide. Flights were scheduled to take advantage of the carrying capacity of the aircraft, and a typical flight schedule for 1982 was:

CR (Campbell River) -> Great Central Lake -> CR
CR -> Awun - Eden -> Ian -> Bonilla lakes -> CR
CR -> Curtis -> Lowe -> Kitlope lakes -> CR
CR -> Long Lake -> CR
CR -> Henderson -> Hobiton lakes -> CR
CR -> Nimpkish Lake -> CR
CR -> Kennedy Lake -> CR

The average flying time to complete one week's distribution of fertilizer solution to these 13 lakes in 1982 was 14.4 hr.

Changes in the delivery schedule were made from time to time to accommodate weather conditions and the need to occasionally adjust lake treatments during the season.

FERTILIZED AREAS OF LAKES

To avoid loss of fertilizer, all treated zones of lakes were placed away from the outlet discharge, and as the target was the limnetic phytoplankton community, treated zones were kept a substantial distance from the lake shore. Fertilizer solution was applied by boat to an area of about 8 km^2 at Great Central Lake during 1970 to 1973. The solution was distributed along six equidistant legs of about 8 km length within the designated fertilized area, at a rate of 189 $L.km^{-1}$ or, at 8 knots vessel speed, approximately 45.4 $L.min^{-1}$.

The area of lakes fertilized by air in 1982 are shown on the attached maps (Figs. 4-16). Fertilizer solution was distributed at Long, Nimpkish, Awun, Eden, Bonilla, Curtis, Kitlope and Lowe lakes by discharging the solution along two legs equal to the length of the designated area to be fertilized, equidistant between the middle of the lake and each shoreline. One half of the fertilizer load was distributed along each leg of the aircraft's track for the entire length of the fertilized area. For Great Central, Kennedy and Henderson Lakes, the fertilizer solution was distributed equally on three legs along the entire length of the designated fertilized area, one leg along the middle of the lake, the others equidistant from the middle and the shoreline. For Ian Lake, distribution was effected by discharging along one leg the length of the designated area in the western basin and two equidistant legs within the designated area in the eastern basin of the lake. Fertilizer solution discharge rates from the aircraft at an average airspeed of 310 $km.h^{-1}$ (160 knots), for each lake treated in 1982 are shown below:

Lake	Discharger rate	Lake	Discharge rate
Awun	1140 $L.min^{-1}$	Bonilla	460 $L.min^{-1}$
Eden	840 $L.min^{-1}$	Great Central	1220 $L.min^{-1}$
Ian	1160 $L.min^{-1}$	Henderson	2636 $L.min^{-1}$
Lowe	950 $L.min^{-1}$	Hobiton	1760 $L.min^{-1}$
Kitlope	2000 $L.min^{-1}$	Kennedy	2550 $L.min^{-1}$
Long	1550 $L.min^{-1}$	Nimpkish	1770 $L.min^{-1}$
Curtis	2500 $L.min^{-1}$		

LAKE TREATMENTS AND FERTILIZER LOADING RATES

Details of methods for calculating desired nitrogen and phosphorus loads to lakes are given in Parsons et al. 1972 and Stockner et al. 1980. Lakes were treated throughout the optimal growing season, which generally required 20 to 26 weekly applications. Some northern mainland lakes received fewer treatments than southern mainland and Vancouver Island lakes due to their shorter growing season. A summary of lake treatments and loading rates is presented in Table 3.

COMPARISON OF OPERATIONAL METHODS

The aerial method was developed for the treatment of lakes without road access, the cost of transporting fertilizer, mixing equipment, boats and personnel to remote lakes was greater than the cost of aerial treatment. Table 4 shows estimated costs for lakes treated by boat and by air, but no direct costs comparisons can be made as no estimates are available for commercial transportation to remote lakes. To treat Kitlope Lake other than by air, would require the trucking or barging of fertilizer and equipment to Bella Coola or Ocean Falls and then airlifting these materials over the mountains to the lake. Accommodation and docking facilities would need to be built for the mixing and application crew and some method of communication with the lake site devised.

The aerial method has an economy of scale, with a decrease in the cost per lake treated with an increase in the number of lakes treated, compared to an increase of cost per lake treated when using boats. Average costs per lake for the preparation and distribution of fertilizer solutions to Henderson, Hobiton, Kennedy, Long and Great Central lakes by boat were: to one lake $20,000 per season, to three lakes $37,000 per lake per season, with no estimates given for all five lakes. Average costs per lake for the preparation and aerial application to all five lakes were $36,000 per lake per season. These estimates were in 1977 dollars and did not include the cost of fertilizer. The estimates were taken from proposals to fertilize lakes solicited by the Department of Supply and Services.

All but the largest lakes were treated in a set, and the addition or substitution of lakes within the flight path were made at little or no additional cost to the program. For example, the aerial treatment of Hobiton Lake was carried out in conjunction with that of Great Central and Henderson lakes for the cost of 0.4 hours additional flying time plus the fertilizer cost. Other benefits of aerial treatment were a more controlled and extensive coverage of lakes surfaces with fertilizer solution. The area of Great Central Lake treated by boat was constrained by the 12 hours required for treatment, while aerial treatment of 5 times that area of the lake required 0.5 hour. An important consideration in the use of the aerial method is the ease of quality control of the operation. The preparation of the fertilizer solution, the areas of the lakes fertilized and the amounts of fertilizer distributed, are quickly and easily controlled. The method also allows for changes in lake treatments to be made without delay.

Any small lake (less than 1000 ha) with easy road access and a well serviced community is more economically treated by boat. Large lakes, or several lakes, and especially lakes with no road access, are more economically treated by air.

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Table 1. Types and composition of fertilizers used in the Lake Enrichment Program, 1970-1982.

Components	Fertilizer	% wt/wt nitrogen and phosphorus content
Mixture of ammonium nitrate and phosphorus	27-14-0[1]	27% N 6% P
Ammonium nitrate	34-0-0	34% N
Ammonium phosphate	11-55-0	11% N 24% P
Organic supplement	Fish Solubles[2]	A source of vitamins and chelating substances

[1]Used in 1970.

[2]Used at dilution of 1:2000 in final treatment solution, discontinued after 1973. Purchased from B.C. Packers, Vancouver, B.C.

Table 2. Lake Fertilization Program, Weekly Treatment Schedule, 1982.

Lake(s)	34-0-0 kg	water kg	11-55-0 kg	water kg	Total tonnes	Start date	End date	Weeks
Great Central	2616	4603	586	2313	10.1	9 May	26 Sept	21
Kennedy-Clayoquot	2842	5002	359	1419	9.6	9 May	26 Sept	21
Henderson	1570	2768	351	1391	6.1	9 May	26 Sept	21
Hobiton	261	459	59	232	1.0	9 May	26 Sept	21
Nimpkish	2616	4603	586	2313	10.1	9 May	26 Sept	21
Long	1952	3433	437	1723	7.5	9 May	26 Sept	21
Bonilla	204	358	46	181	0.8	9 May	26 Sept	21
Awun	351	617	78	308	1.4	9 May	26 Sept	21
Eden	374	658	84	331	1.4	9 May	26 Sept	21
Ian	945	1664	211	834	3.7	9 May	26 Sept	21
Curtis	663	1134	149	585	2.5	9 May	26 Sept	21
Lowe	272	481	61	240	1.1	9 May	26 Sept	21
Kitlope	882	1551	198	780	3.4	30 May	26 Sept	18

Table 3. Summary of Lake Treatments and Loading Rates, 1970 to 1982.

Lake	Year	Total Seasonal Fertilizer Additions Tonnes - Description				Start date	Duration weeks	N:P ratio
Great Central	70	90.1	27-14-0			1 May	20	10:1
Great Central	71	81.6	34-0-0	27.2	11-55-0	1 May	20	10:1
Great Central	72	68.0	34-0-0	22.7	11-55-0	1 May	20	10:1
Great Central	73	68.0	34-0-0	22.7	11-55-0	1 May	20	10:1
Henderson	76	27.2	34-0-0	9.1	11-55-0	5 July	16	10:1
Henderson*	77	34.9	34-0-0	6.9	11-55-0	2 June	22	*
Hobiton*	77	2.86	34-0-0	0.60	11-55-0	2 June	22	*
Great Central	77	48.1	34-0-0	16.9	11-55-0	2 June	22	10:1
Long	77	50.8	34-0-0	17.4	11-55-0	2 June	22	10:1
Henderson	78	40.8	34-0-0	13.6	11-55-0	19 April	26	10:1
Hobiton	78	3.4	34-0-0	1.13	11-55-0	19 April	26	10:1
Kennedy - Clayoquot	78	42.2	34-0-0	14.1	11-55-0	19 April	26	10:1
Great Central	78	57.8	34-0-0	19.3	11-55-0	19 April	26	10:1
Long	78	65.3	34-0-0	21.8	11-55-0	19 April	26	10:1
Henderson	79	40.8	34-0-0	9.1	11-55-0	16 April	26	15:1
Hobiton	79	6.8	34-0-0	1.53	11-55-0	16 April	26	15:1
Kennedy - Clayoquot	79	41.7	34-0-0	9.3	11-55-0	16 April	26	15:1
- Main	79	56.7	34-0-0	12.7	11-55-0	16 April	26	15:1
Great Central	79	41.9	34-0-0	9.4	11-55-0	16 April	16	15:1
Kitlope	79	31.8	34-0-0	7.3	11-55-0	7 May	18	15:1
Lowe	79	5.0	34-0-0	1.0	11-55-0	7 May	18	15:1
Awun	79	9.1	34-0-0	2.0	11-55-0	23 April	26	15:1
Eden	79	9.7	34-0-0	2.2	11-55-0	23 April	26	15:1
Ian	79	24.6	34-0-0	5.50	11-55-0	23 April	26	15:1
Mercer	79	2.4	34-0-0	0.53	11-55-0	23 April	26	15:1

*No phosphorus added for 10 weeks 26 July to 26 September.

Table 3 (cont'd)

Lake	Year	Total Seasonal Fertilizer Additions (Tonnes - Description)				Start date	Duration weeks	N:P ratio
Great Central	80	68.0	34-0-0	15.2	11-55-0	14 April	26	15:1
Henderson	80	40.8	34-0-0	9.2	11-55-0	14 April	26	15:1
Hobiton	80	6.0	34-0-0	1.4	11-55-0	4 May	23	15:1
Kennedy - Main	80	56.7	34-0-0	12.7	11-55-0	14 April	26	15:1
- Clayoquot	80	41.8	34-0-0	9.3	11-55-0	14 April	26	15:1
Awun	80	9.1	34-0-0	2.0	11-55-0	14 April	26	15:1
Eden	80	9.7	34-0-0	2.2	11-55-0	14 April	23	15:1
Ian	80	24.6	34-0-0	5.5	11-55-0	14 April	26	15:1
Lowe	80	10.0	34-0-0	2.1	11-55-0	4 May	20	15:1
Kitlope	80	31.8	34-0-0	7.2	11-55-0	1 June	18	15:1
Bonilla	80	12.5	34-0-0	2.6	11-55-0	4 May	20	15:1
Curtis	80	5.1	34-0-0	1.1	11-55-0	4 May	20	15:1
Devon	80	3.2	34-0-0	0.71	11-55-0	4 May	20	15:1
Morice	80	93.5	34-0-0	21.1	11-55-0	1 June	18	15:1
Great Central	81	68.0	34-0-0	15.2	11-55-0	5 April	26	15:1
Henderson	81	40.8	34-0-0	9.2	11-55-0	5 April	26	15:1
Hobiton	81	6.8	34-0-0	1.5	11-55-0	5 April	26	15:1
Kennedy - Clayoquot	81	36.9	34-0-0	8.2	11-55-0	12 April	23	15:1
Awun	81	8.8	34-0-0	2.0	11-55-0	12 April	25	15:1
Eden	81	9.4	34-0-0	2.1	11-55-0	12 April	25	15:1
Ian	81	23.6	34-0-0	5.2	11-55-0	12 April	25	15:1
Lowe	81	12.5	34-0-0	2.8	11-55-0	12 April	25	15:1
Kitlope	81	31.8	34-0-0	7.2	11-55-0	10 May	18	15:1
Bonilla	81	14.8	34-0-0	3.5	11-55-0	12 April	25	15:1
Curtis	81	12.9	34-0-0	2.9	11-55-0	12 April	25	15:1

Table 3 (cont'd)

Lake	Year	Total Seasonal Fertilizer Additions Tonnes - Description				Start date	Duration weeks	N:P ratio
Great Central	82	64.9	34-0-0	12.3	11-55-0	9 May	21	15:1
Henderson	82	32.9	34-0-0	7.4	11-55-0	9 May	21	15:1
Hobiton	82	5.5	34-0-0	1.2	11-55-0	9 May	21	15:1
Ian	82	19.8	34-0-0	4.4	11-55-0	2 May	21	15:1
Kitlope	82	15.9	34-0-0	3.6	11-55-0	30 May	18	15:1
Long	82	41.0	34-0-0	9.2	11-55-0	10 May	21	15:1
Lowe	82	5.7	34-0-0	1.3	11-55-0	10 May	21	15:1
Nimpkish	82	54.9	34-0-0	12.3	11-55-0	9 May	21	15:1
Awun	82	7.4	34-0-0	1.6	11-55-0	9 May	21	15:1
Bonilla	82	4.3	34-0-0	1.0	11-55-0	9 May	21	15:1
Curtis	82	13.9	34-0-0	3.1	11-55-0	9 May	21	15:1
Eden	82	7.9	34-0-0	1.8	11-55-0	9 May	21	15:1
Kennedy - Clayoquot	82	59.7	34-0-0	7.5	11-55-0	10 May	21	25:1

Table 4. Application cost comparisons ($000's), 1983 dollars.

Lake	Boat Application				Aerial Application		
	Fertilizer	Transport	Facilities	Operations[1]	Facilities	Operations	Flying
Nimpkish	13.6	4.0	10.0	41.0			37.2
Kennedy	13.0	3.0	10.0	41.0			34.1
Great Central	13.6	3.0	10.0	41.0			
Henderson	8.1						80.6
Hobiton	1.6						
Awun	1.8						
Eden	1.9	costs not available			51	604.7	
Ian	4.9						142.6
Yakoun	2.9						
Kitlope	4.6						
Bonilla	1.0						
Curtis	1.3						120.9
Long	10.1						49.6

[1]Operations includes rentals, wages and other operational expenses.

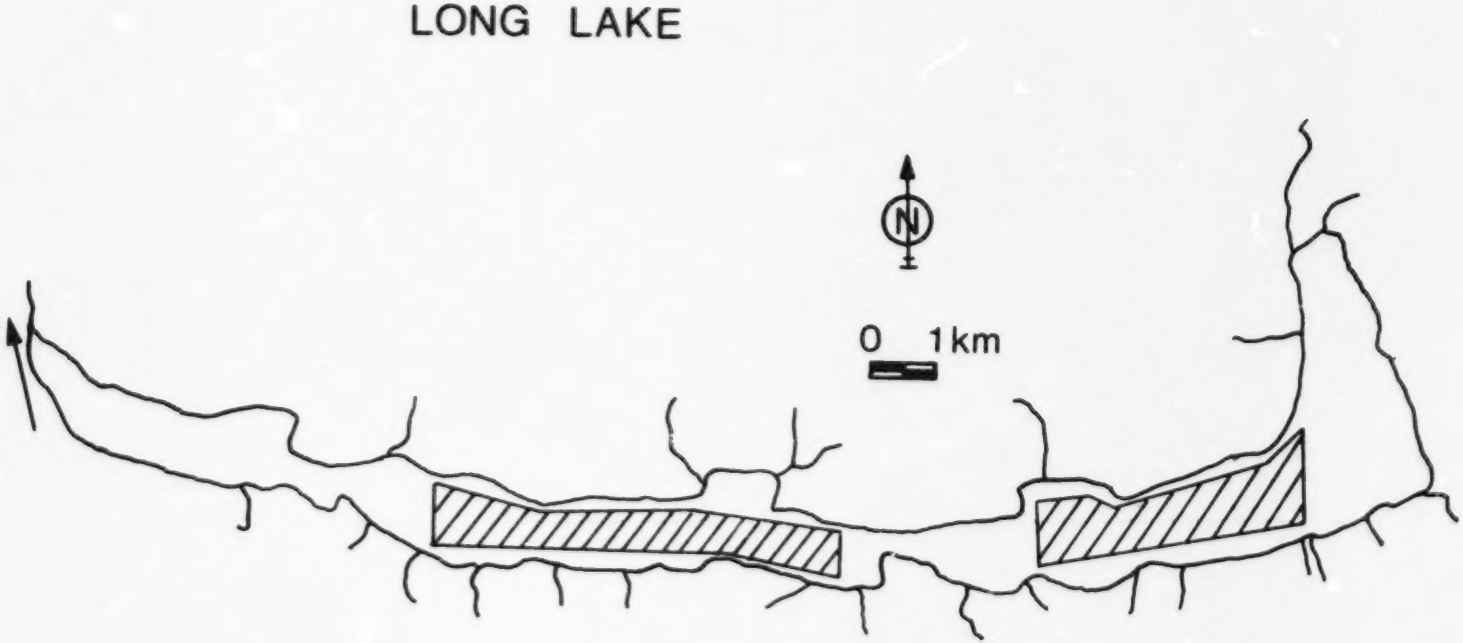

Fig. 4. Long Lake, shaded area indicates fertilized zone.

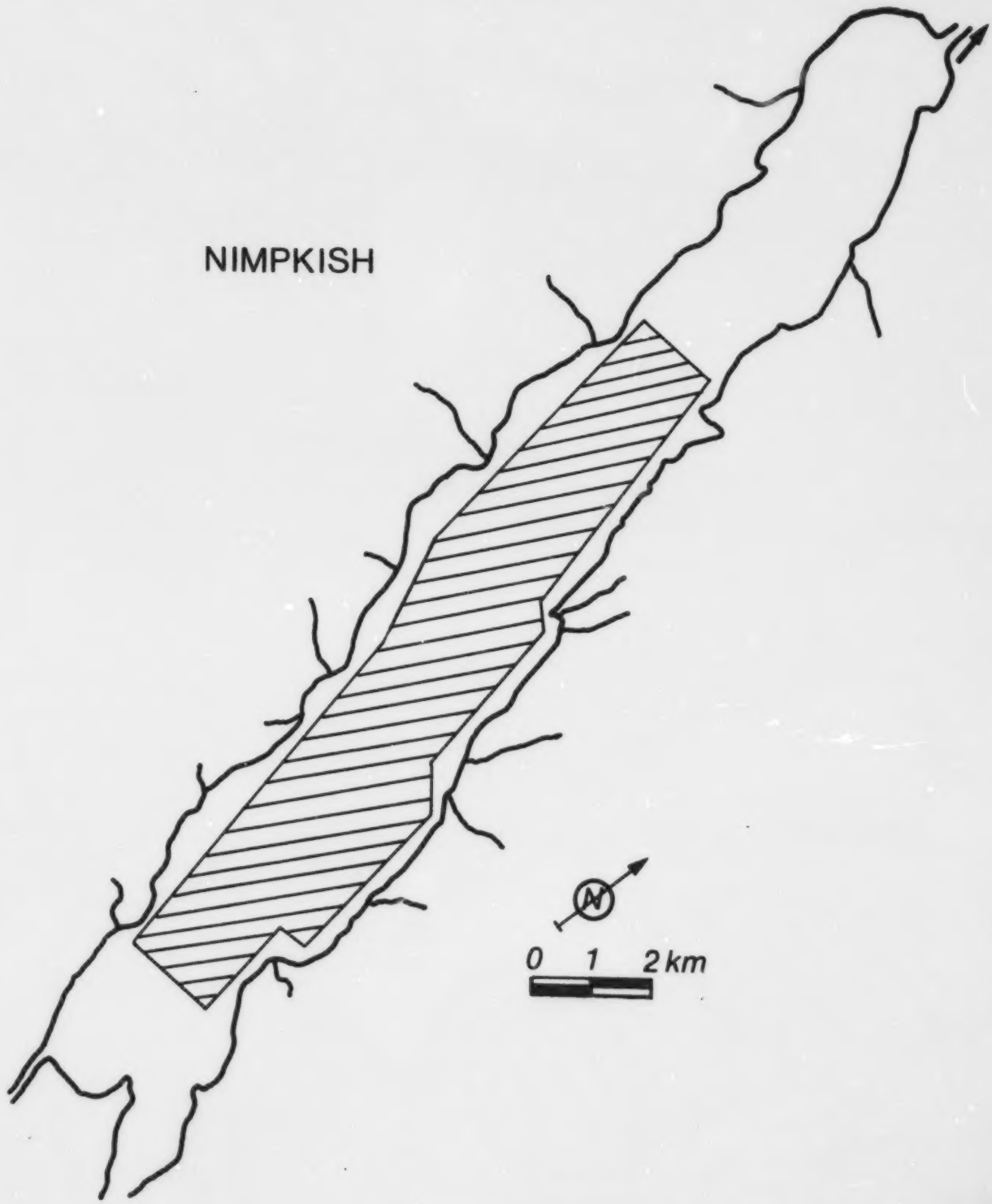

Fig. 5. Nimpkish Lake, shaded area indicates fertilized zone.

Fig. 6. Ian Lake, shaded area indicates fertilized zone.

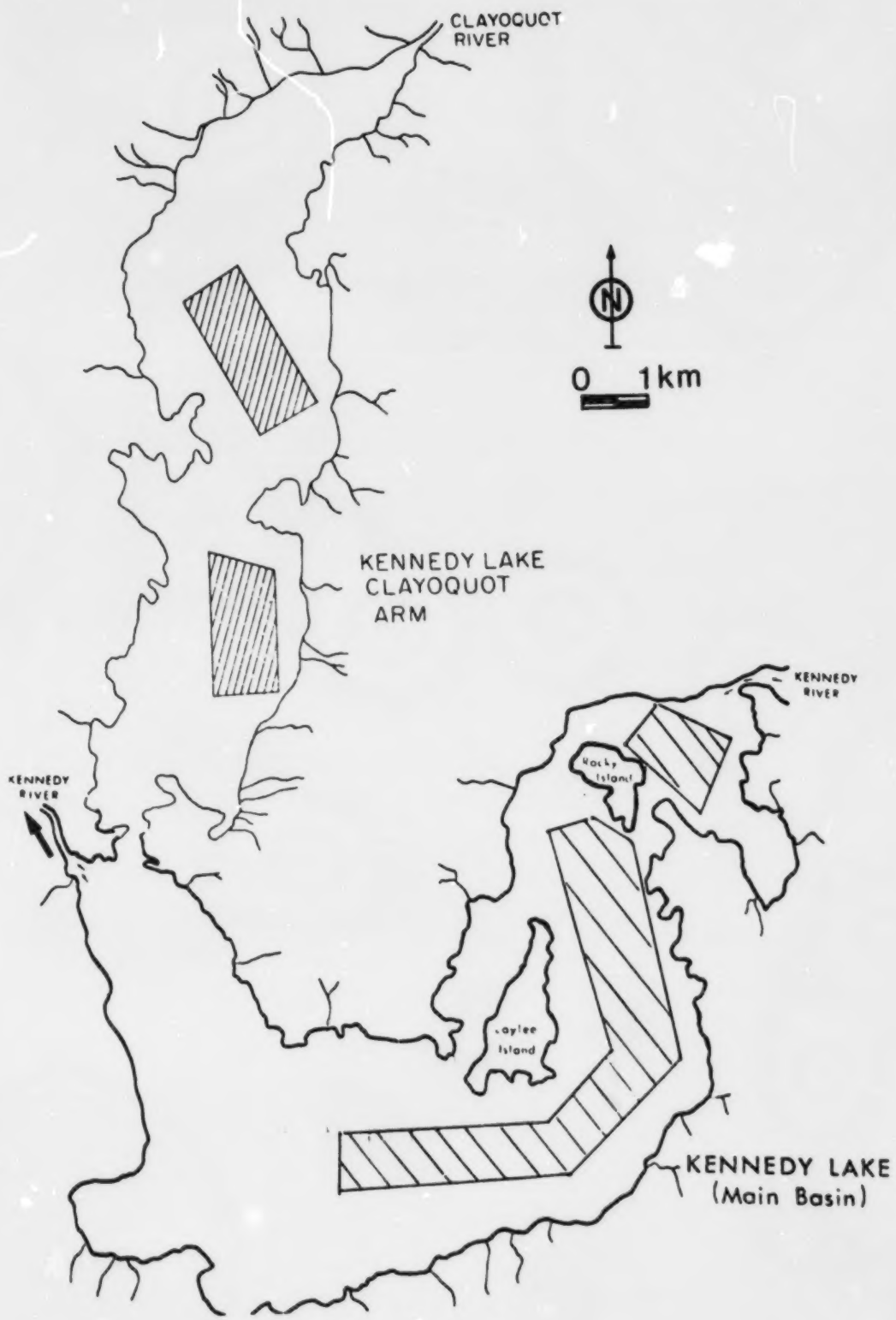

Fig. 7. Kennedy Lake, shaded area indicates fertilized zone.

Fig. 8. Awun Lake, shaded area indicates fertilized zone.

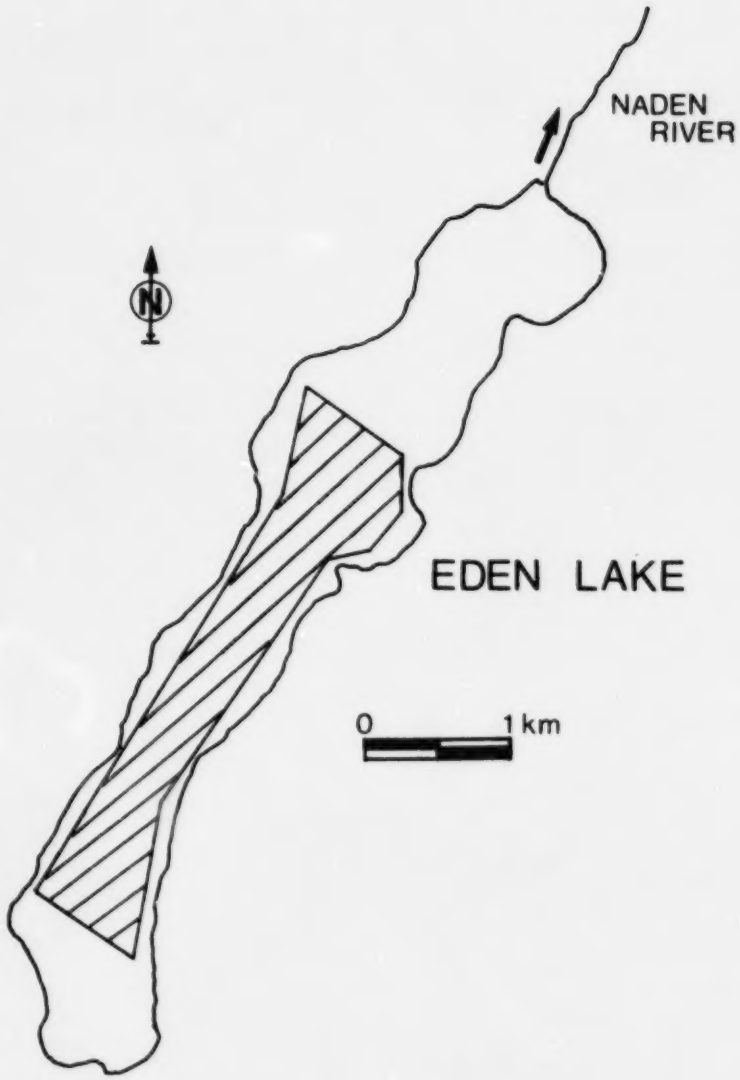

Fig. 9. Eden Lake, shaded area indicates fertilized zone.

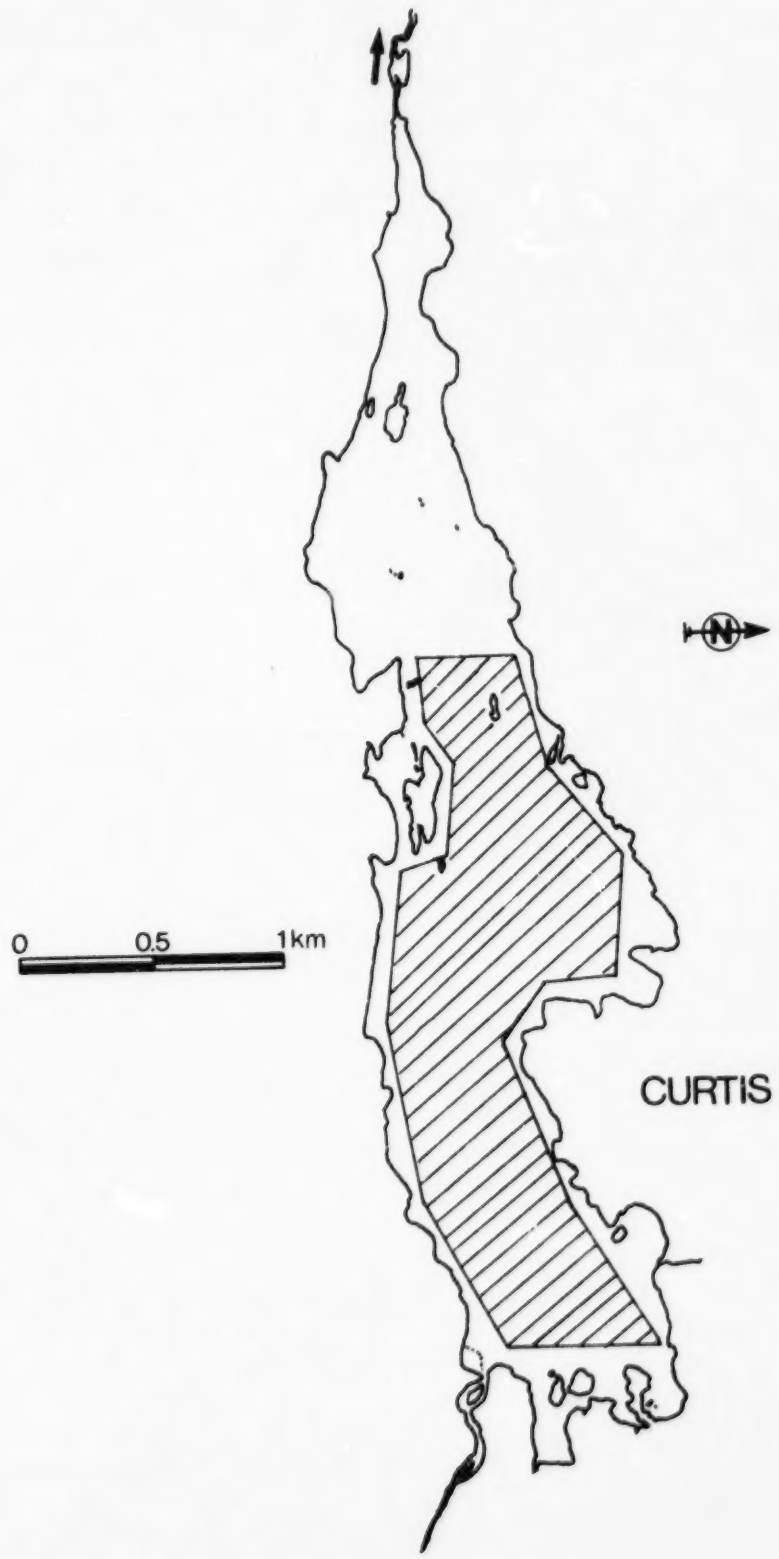

Fig. 10. Curtis Lake, shaded area indicates fertilized zone.

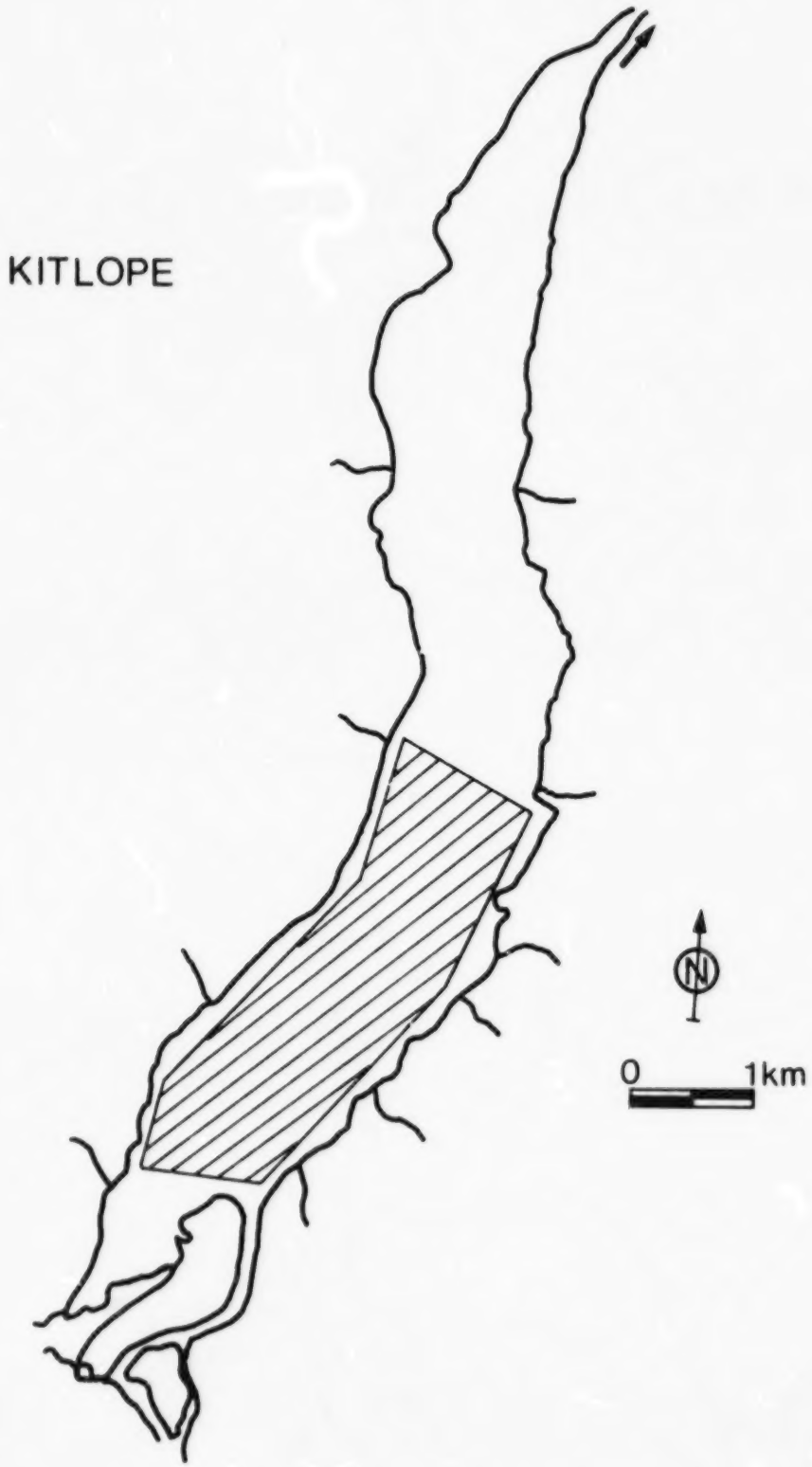

Fig. 11. Kitlope Lake, shaded area indicates fertilized zone.

Fig. 12. Bonilla Lake, shaded area indicates fertilized zone.

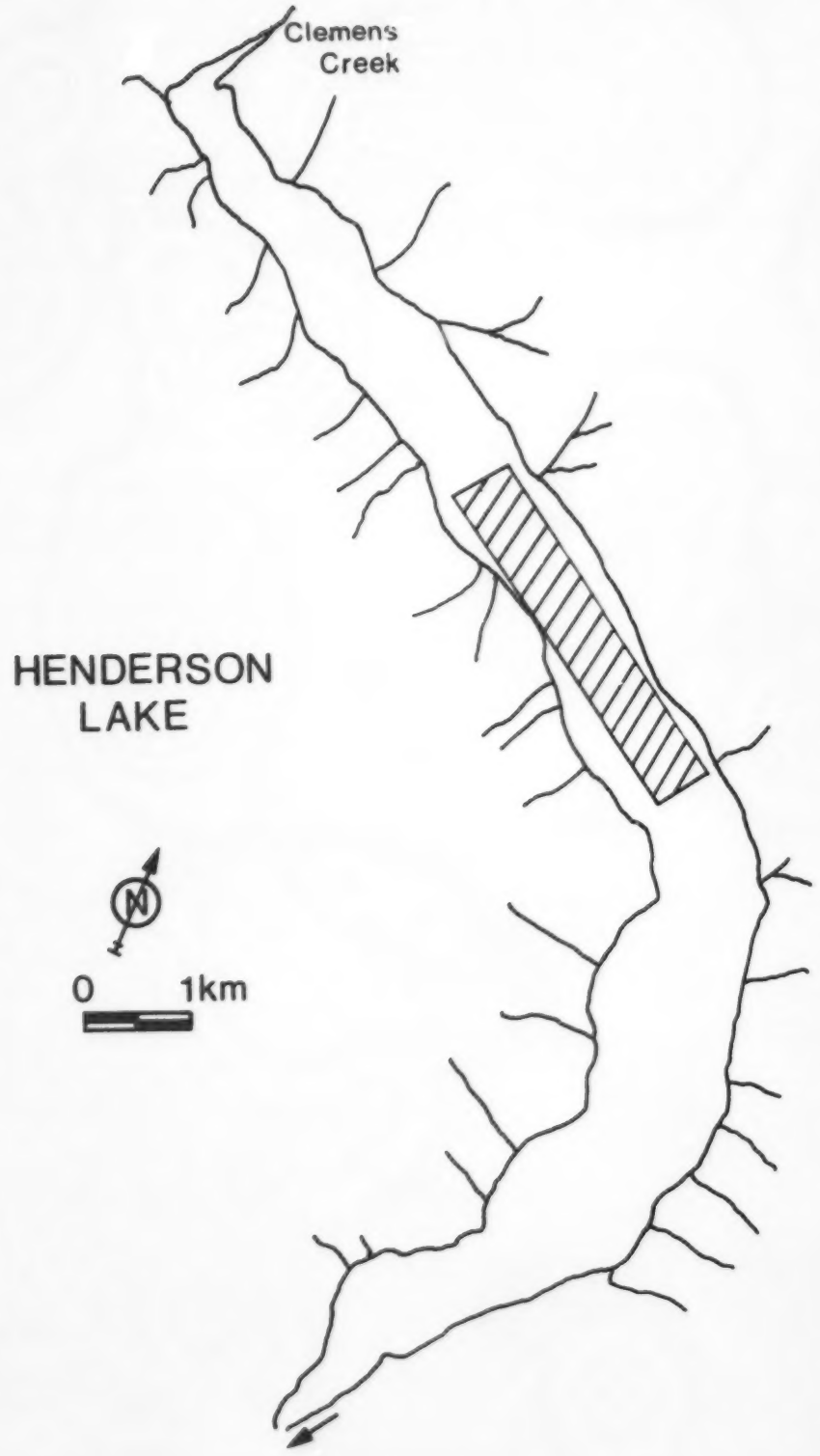

Fig. 13. Henderson Lake, shaded area indicates fertilized zone.

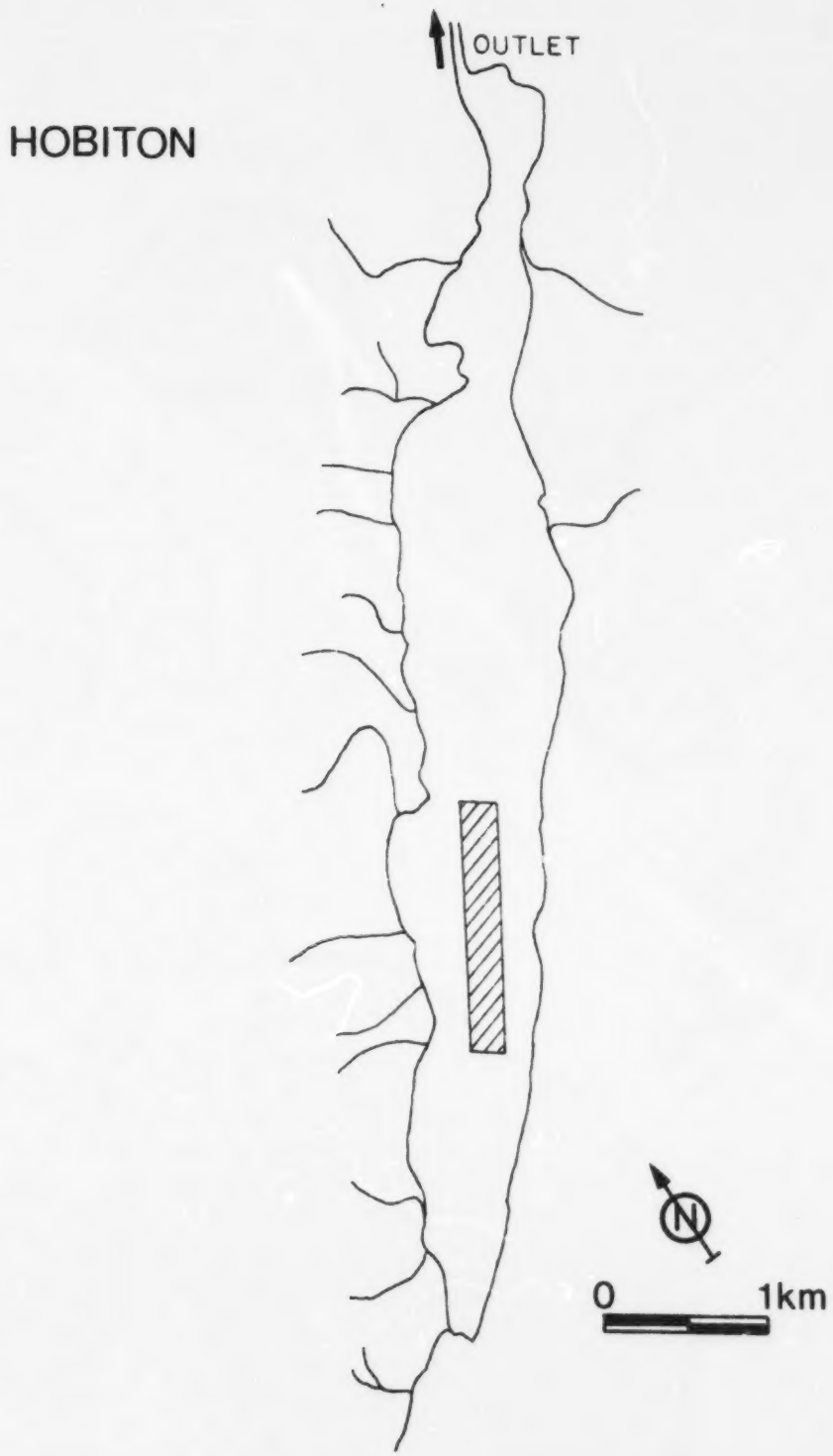

Fig. 14. Hobiton Lake, shaded area indicates fertilized zone.

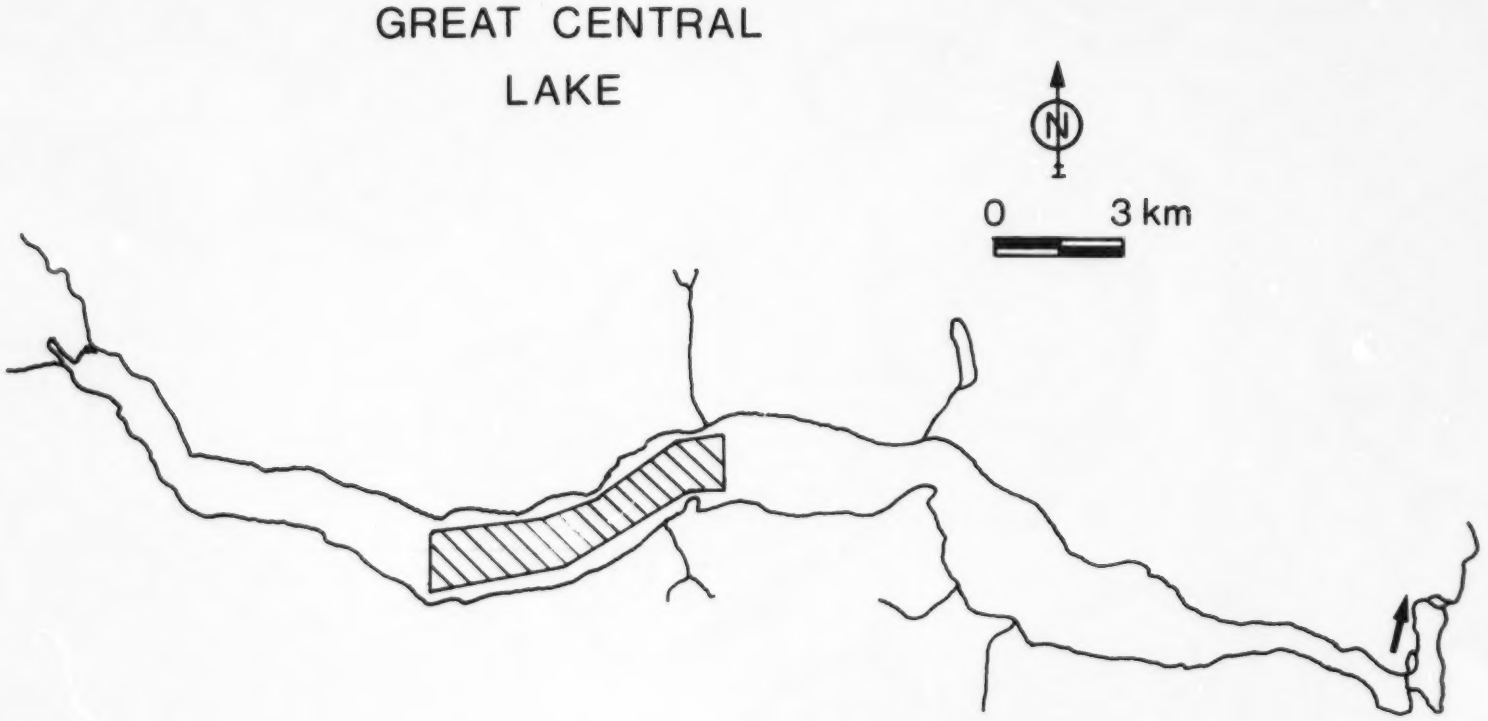

Fig. 15. Great Central Lake, shaded area indicates fertilized zone.

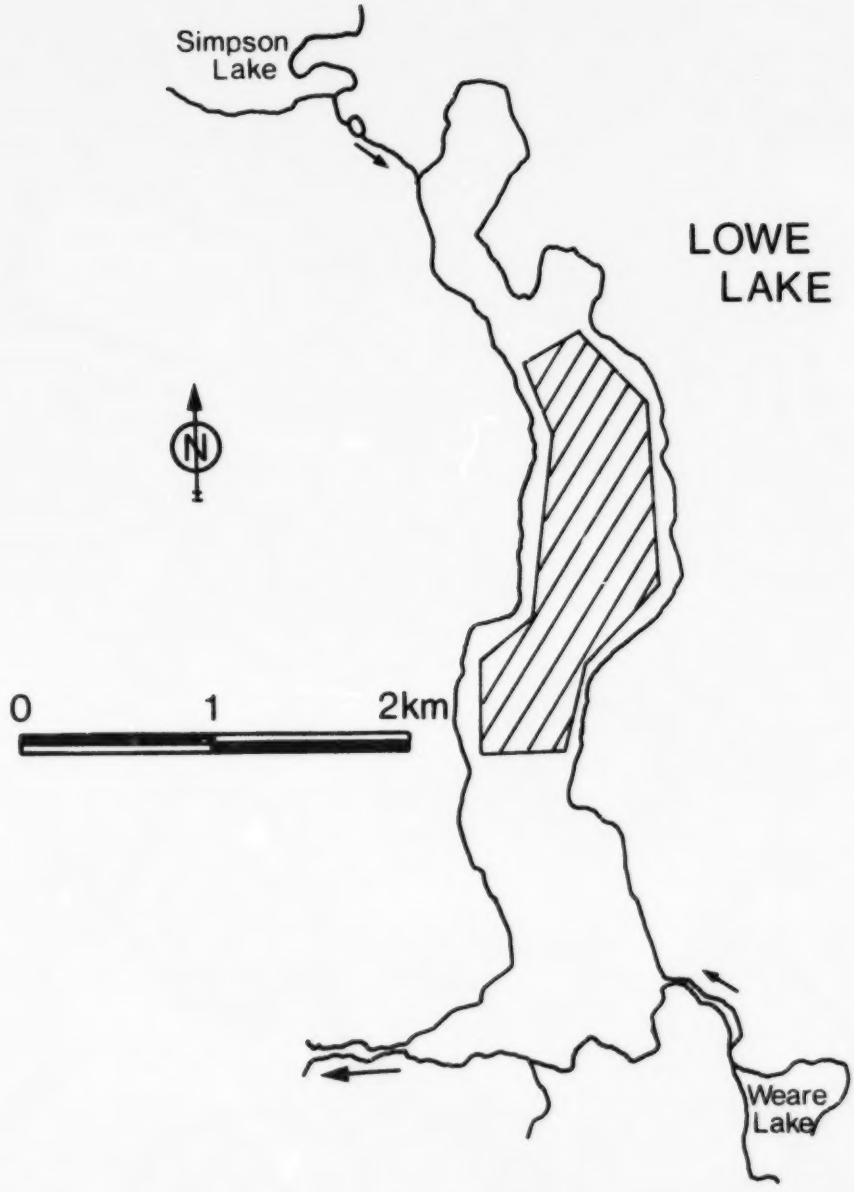

Fig. 16. Lowe Lake, shaded area indicates fertilized zone.

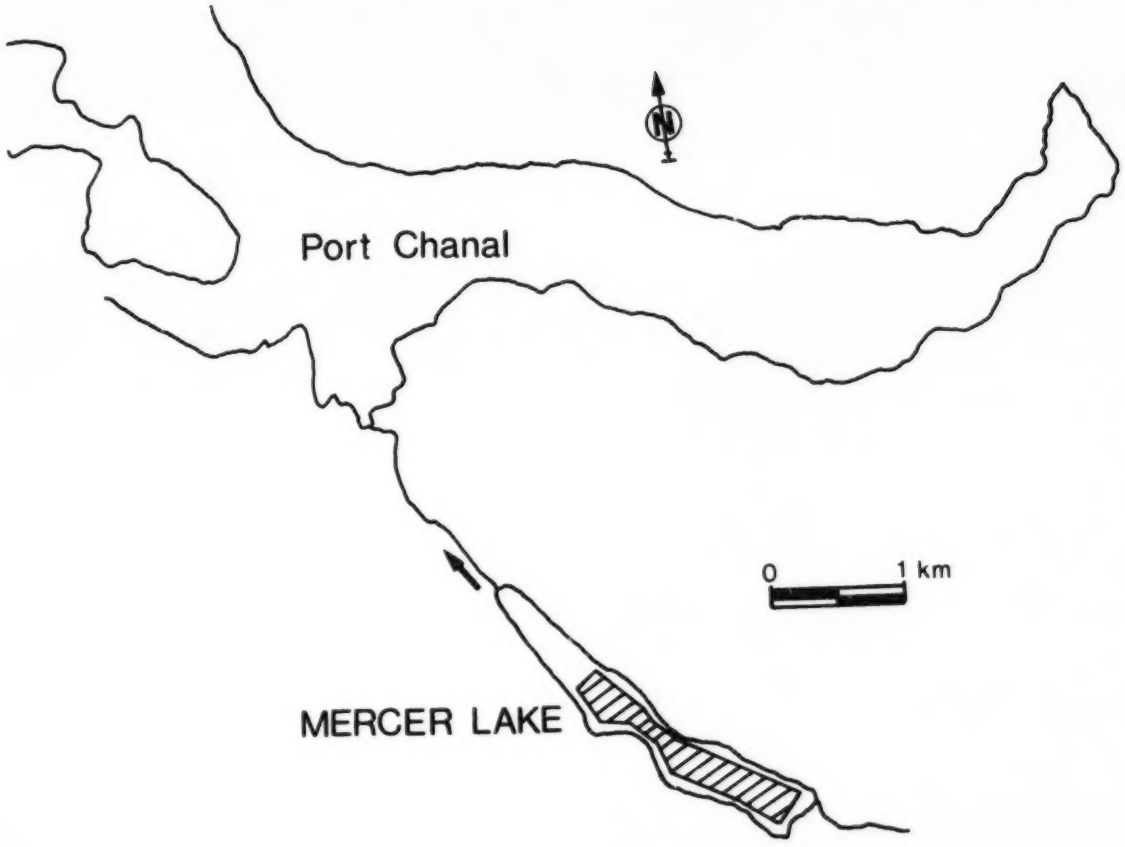

Fig. 17. Mercer Lake, shaded area indicates fertilized zone.

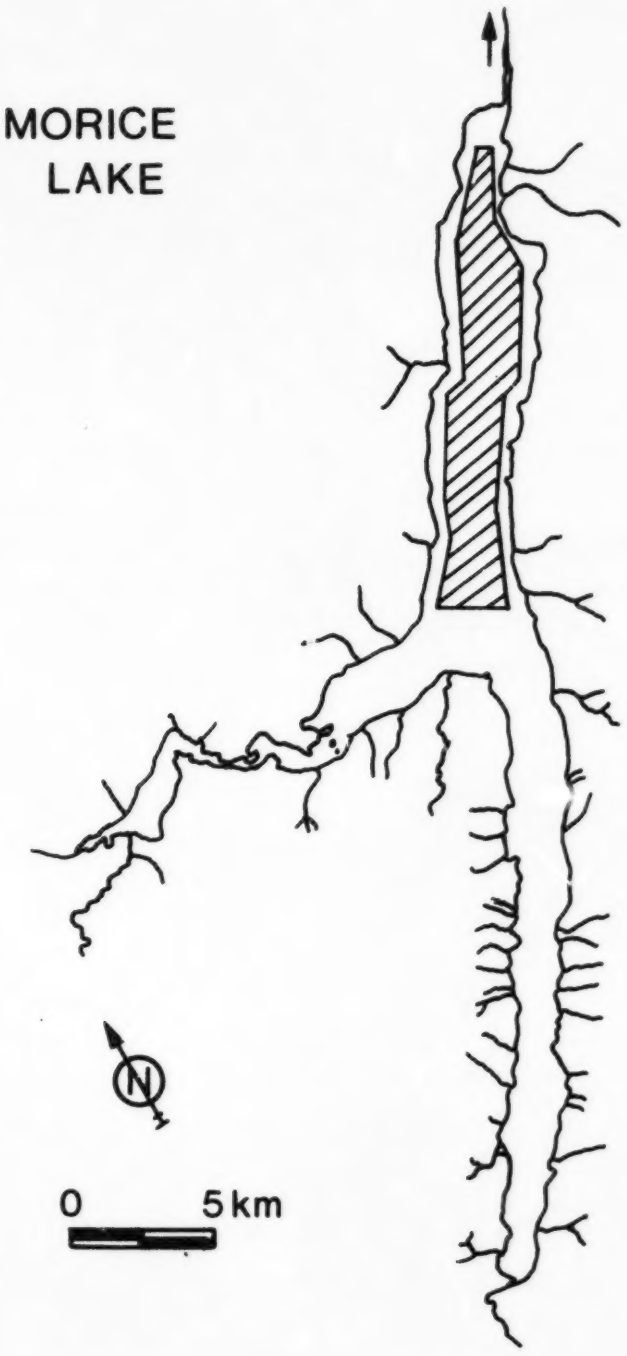

Fig. 18. Morice Lake, shaded area indicates fertilized zone.

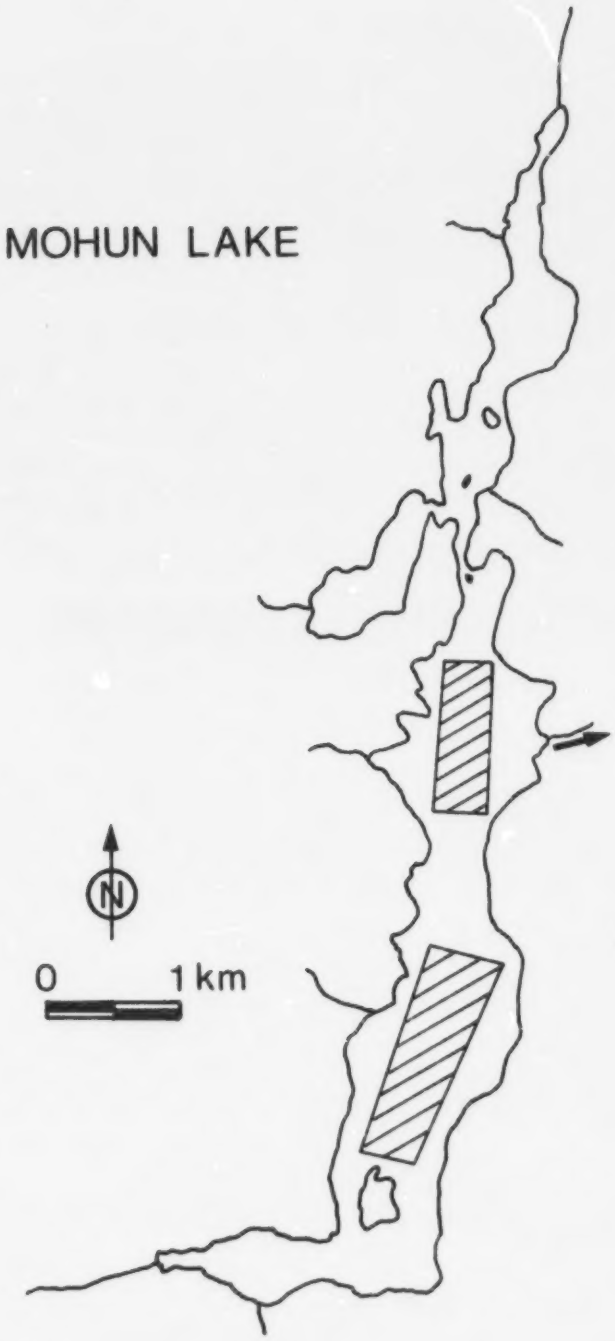

Fig. 19. Mohum Lake, shaded area indicates fertilized zone.

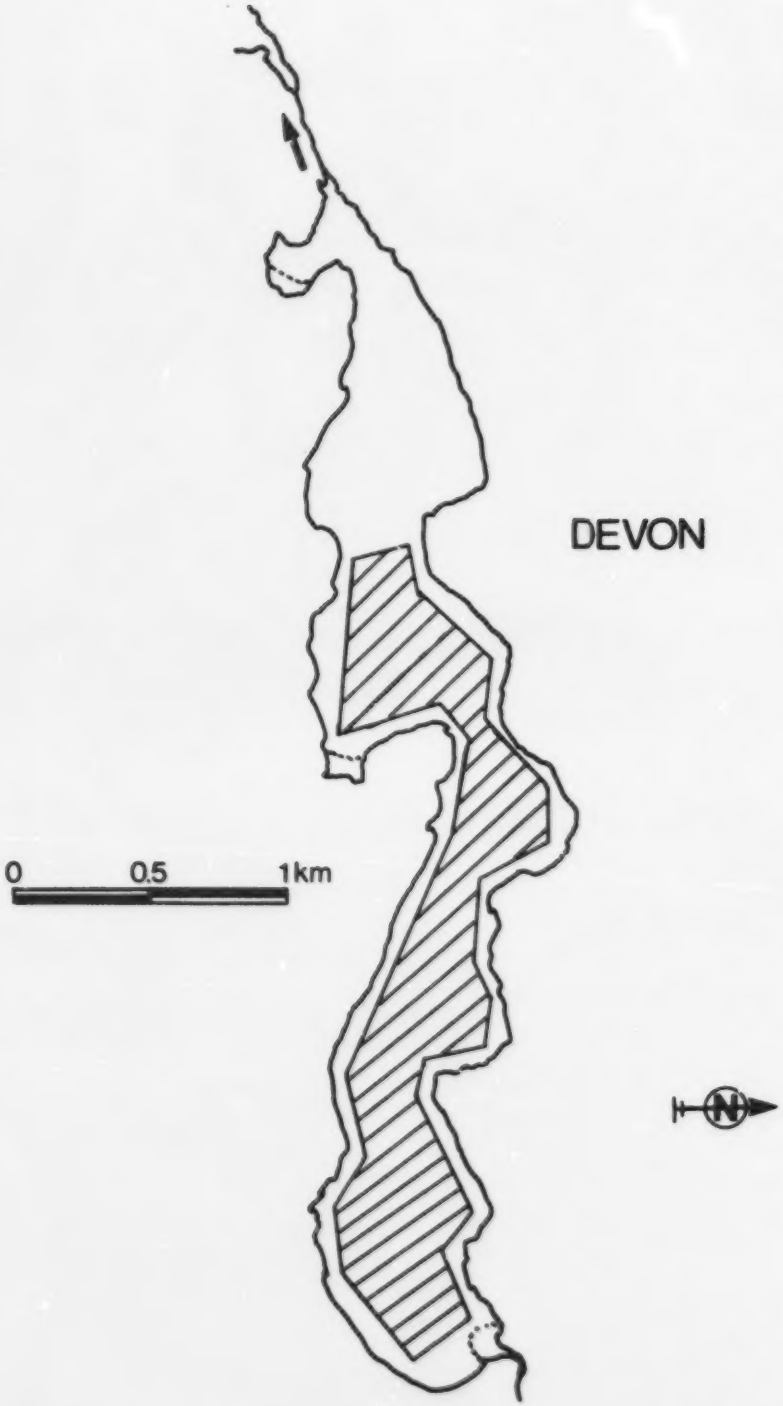

Fig. 20. Devon Lake, shaded area indicates fertilized zone.